NEW ELEVATION MODELS OF THE CZECH REPUBLIC

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Abstract

The following presentation provides information about the new elevation models of the Czech Republic and their cartographic applications. The project is currently running in cooperation of the Czech Office for Surveying, Mapping and Cadastre, the Ministry of Defence and the Ministry of Agriculture of the Czech Republic. Airborne laser scanning technology has been chosen as the main data capture method. Basic parameters, workflow and final products – two digital terrain models and a digital surface model, their vertical accuracy and application possibilities including a hard-cartography application for the production of the Basic Maps of the Czech Republic are noted in this presentation.

Keywords: elevation models, laser scanning, contour line

1. Introduction

Presently, during the technical and technological development of geomatics and cartography, new methods of remote sensing are used. A new phenomenon is the technology of Airborne Laser Scanning (ALS) used for the mapping of altimetry. High quality Digital Surface Models and Digital Terrain Models are created in many countries. ALS enables the capture of huge amounts of elevation data of a relatively good quality. The Czech Republic started gathering of ALS elevation data in 2009. Currently 2/3 of Czech territory is covered by ALS data with a density better than 1,5 ps/m^2. The ALS project launched in 2008 has been realized through the cooperation of the Czech Office for Surveying, Mapping and Cadastre (COSMC), the Ministry of Defence and the Ministry of Agriculture of the Czech Republic. It is expected to finish the raw data acquisition at the end of 2013. At the same time, the production of a Digital Terrain Model of the Czech Republic – 4th generation (DMR 4G) is to be finished following by the Digital Terrain Model of the Czech Republic – 5th generation (DMR 5G). DMR 5G is considered as the perspective fundamental elevation model of the Czech Republic and together with the files of 3D terrain edges it will create the Fundamental Base of Elevation Data of the Czech Republic. The Baltic Elevation System after Adjustment is used for this data.

The formation of new elevation databases with substantially better data quality motivates for data applications not only in Geographic Information Systems (GIS) but also within the framework of the conventional cartography. In those circumstances, new requirements for the visualization of elevation data have arisen. Once again there is a need for cartographic

generalization as new elevation data are more detailed and of better accuracy. DMR 5G is now of such a quality that this model can be used even for detailed high quality contour lines generation dedicated for applications in large scale maps and city plans.

The Land Survey Office, as a state mapping agency of the Czech Republic, focuses basically on three applications of the new elevation models. First, the office creates products for visualization of altimetry in the Geoportal of the COSMC using shaded relief or simplified contour lines. A second application is the production of the Fundamental Contour Lines of the Czech Republic predestined for applications in large scale maps and plans. A third, and basically the most difficult application, is the ambition to produce high quality contour lines generalized for different map scales. In this application, it will be necessary to solve challenging algorithms and data processes of cartographic generalization of contour lines for particular map scale with topological relations to other geographic features, respectively to the cartographic symbols.

The goal of this article is to present the new elevation models of the Czech Republic and the activities and approaches of the Land Survey Office in the field of elevation cartographic applications – especially for high quality contour lines production.

2. The Airborne Laser Scanning of the Czech Republic – Products

The Airborne Laser Scanning of the Czech Republic is realized by the scan system LiteMapper 6800, provided by the company IGI mbH, using the airborne laser scanner Riegl LMS Q680. The parameters of ALS are chosen in such a way that the density of the point cloud reaches approximately 1,5 ps/m^2. The altitude of ALS is approximately 1200 m above the average elevation of terrain with 50 % overlapped scanning strips. The raw data are post-processed by the software RiPROCESS, RiWORLD and RiANALYZE, provided by the company Riegl, GmbH. The technologies SCOP++ and DTMaster from the INPHO Company (currently INPHO and TRIMBLE Company) are used for subsequent processing of altimetry data and production of the final elevation products. Final smoothing of the DMR 5G is processed by high quality utilities of the software Atlas DMT that is a product of the Czech company ATLAS, s.r.o.

The final products are:

DMR 4G – consists from regularly gridded elevation points (in grid 5 × 5 m) provided by coordinates [X, Y, H] with the root mean square error 0,30 m in bare terrain and 1 m in terrain covered by dense vegetation. This model has been created for 2/3 territory of the Czech Republic and it is planned to cover entire territory of the Czech Republic by the end of 2013.

DMR 5G – consists of the irregularly distributed elevation points [X, Y, H] creating nodes of the triangulated irregular network (TIN). Currently this model represents the most accurate elevation data covering territory of the Czech Republic. Root mean square error of the elevation is 0,18 m in bare terrain and 0,3 m in terrain covered by dense vegetation. This model has been created for 1/3 territory of the Czech Republic. Completion of this model for the entire territory of the Czech Republic is planned for the end of 2015.

The Digital Surface Model of the Czech Republic - 1st generation (DMP 1G) consists of the irregularly distributed elevation points [X,Y, H] creating TIN. This model displays the ground surface (DMR 5G in bare areas) and the top surfaces of the objects situated on it, such as roofs, tree crowns, etc. DMP 1G is designed for computer analysis of visibility and other analysis in the field of crisis management and defense. Completion of this model for the entire territory of the Czech Republic is planned for the end of 2015.

3. Fundamental Contour Lines of the Czech Republic

New Fundamental Contour Lines of the Czech Republic should be created in the contour line interval of 1 m supplemented by contour lines with interval of 0,5 m within flat areas. The basic accuracy requirement on Fundamental Contour Lines is to keep the accuracy of elevation points back interpolated from contour lines better then 0,5 m related to the terrain. Fundamental Contour Lines are dedicated mainly for presentation of terrain altimetry in large scale maps and in GIS applications usually together with DMR 5G. Contour lines are still considered as a best tool for representation of terrain character and tendency in wider areas while DMR 5G should be used as a source data in GIS applications for measurement of terrain elevation in particular spot.

There is a lot of software for contour lines generation on the market, but it usually works within defined theoretical constrains with well prepared digital terrain models. But in practice, a serious problem is that ordinary digital terrain models usually do not fit with the software required parameters. First problem is DMR 5G created from ALS does not include elevation data from water areas such as streams, rivers, ponds, dams, etc. In DMR 5G, even with declared accuracy, many elevation points are missing in deep ravines and in rugged or rocky areas. Uncertainty of elevation of shore lines (river banks) that create basic break[1] and stop[2] model lines, causes serious topological errors of generated contour lines (Fig. 1).

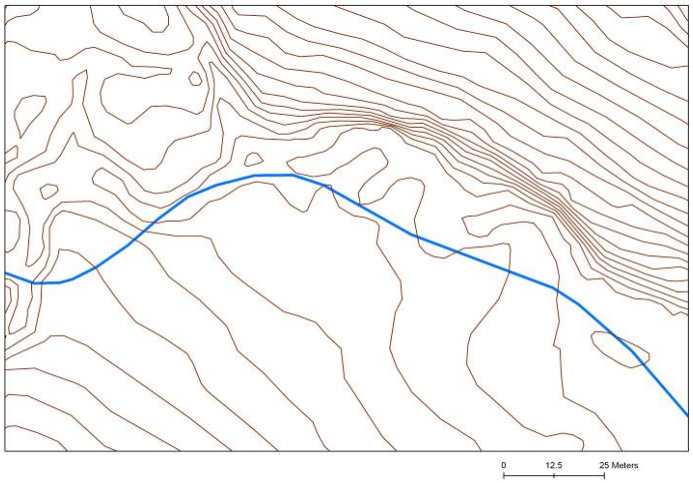

Figure 1: Example of topological errors (see the crossing of stream and contour lines)

[1] Break line is 3D polyline representation of terrain edge where terrain sharply changes the gradient.

[2] Stop line is 3D polyline representation of terrain elevation shift or shore line (banks of rivers, dams or ponds).

Another problem is the discoincidence of other geographical features, kept in the Fundamental Base of Geographic Data of the Czech Republic (called ZABAGED®), to the DMR 5G and to the derived contour lines. ZABAGED® was created in the nineties of the last century by data digitalization from the Basic Maps of the Czech Republic in scale of 1 : 10 000. Data from ZABAGED® are still burdened by position errors caused by the generalization of maps and also by random survey errors. Position disharmony of ZABAGED® and DMR 5G is up to 5 meters or even more. This is the reason why geographic features of ZABAGED® cannot be used as a model's break or stop lines for generating algorithms of the Fundamental Contour Lines.

Solution of disharmony DMR 5G and ZABAGED® has led to the new digitalization of the most important valley lines, like streams (narrower than 2 m), river banks and shore lines of water areas, firstly. Use of stereophotogrammetry only is a very time consuming process and therefore it was deemed to be insufficient way for Fundamental Contour Lines production - to be finished for entire territory of the Czech Republic by the end of 2016. However, use of stereophotogrammetry in addition to digitizing the appropriate features using 2D technology above orthophoto or shaded relief has offered acceptable results. Elevation (H) is added to those 2D features by interpolation from DMR 5G. The down-gradient continuity of a main stream course is controlled automatically starting from the stream spring to the influence, or from dam to dam (Fig. 2). The software application was developed by the experts of the Land Survey Office.

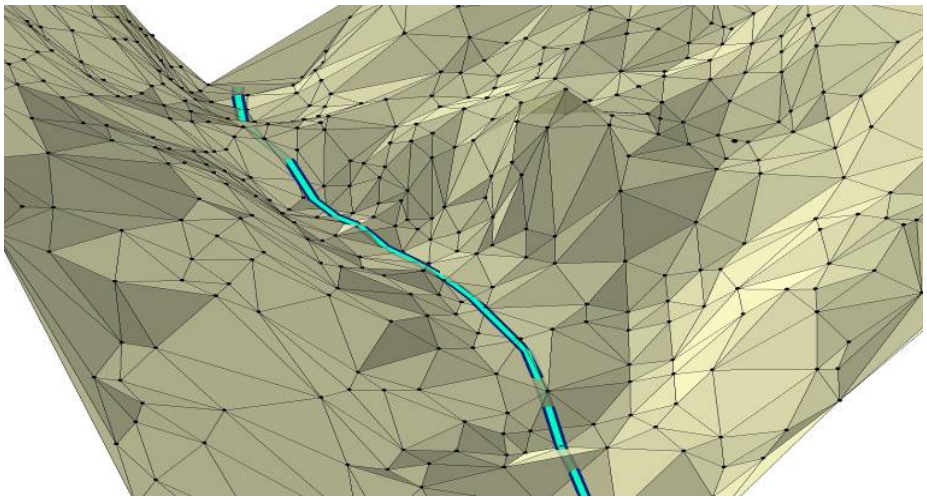

Figure 2: Down-gradient continuity of the stream

Because terrain close to a stream, a river bed or a river's bank is usually very complicated and rugged, it is necessary for generation of contour lines firstly generalize DMR 5G within an appropriate buffer around the above mentioned features. All DMR 5G elevation points within the buffer created around those feature lines are marked not to be not used for contour lines generation. One or two meter buffers are appropriate for a map scale of 1 : 5 000. Using those parameters and approach the stop or break lines for model are a little bit below than the rest of DMR 5G points around those feature lines. The contour lines are then curved in the right position related to the feature lines and depict the valley lines in the right way. Of course, despite of a relatively fine terrain generalization, the accuracy of contour lines is negatively

impacted. It is a compromise enabled by the fact that users still have possibility to use ungeneralized DMR 5G to evaluate correct terrain elevation in a particular spot.

Figure 3: Screenshot of Fundamental Contour Lines and valley line (stream) coincidence

The resultant Fundamental Contour Lines depict continuous surface of terrain areas by visualization of continuous contour lines only. 3D polylines are used as break lines for streams narrower than 2 m. For bank lines of streams (wider than 2 m) and rivers or water areas 3D stop lines are used in model. Other stop lines are used only extraordinarily, usually in the spot of gross terrain discontinuity (retaining wall, important rocks, etc.). Natural banks, terraces, embankments around roads and railways or escarpments are depicted as a continuous surface only by contour lines. Cartographic technology and tools make contour lines only invisible in the areas where ordinary contour lines are too close each other. In GIS applications users can use software tool to survey a more precise spot elevation from invisible DMR 5G, available on the background of the software application.

Figure 4: Example of continuous Fundamental Contour Lines

4. The cartographic contour line creation for the medium scale base maps

The representation of the altimetry in the medium scale maps requires topologically correlated generalization of the contour lines and related geographic features, with regard to the necessary generalization of information content and the way of information representation in those maps. Czech cartographers have dealt with automatic cartographic generalization of geospatial information organized in the elementary vector database for many years. Despite, the generalization of altimetry was not a subject of great scientific interest because the altimetry of the medium scale maps was solved manually in the last century and the updating of the basic elevation data did not has an essential effect on changes in the representation of the altimetry in those maps. At present with respect to the production of new altimetry of the Czech Republic with higher accuracy, there is a ambitions to generate a new representation of altimetry for the medium scale maps, especially of 1 : 10 000 and 1 : 25 000.

The basic requirement of the model generalization algorithm, using the advanced software technology, is suitable execution of the break and stop lines generalization firstly. It is necessary to generalize those 3D lines in the horizontal correlation to the other 2D geographic features of ZABAGED®, respectively to their cartographic representation. Initial data model must contain, next to the elevation model, different types of break lines and stop lines topologically related to the basic elevation model. Therefore, the Land Survey Office has initiated the digitalization of the main terrain break lines using stereophotogrammetry. Software Topol[3] and Atlas DMT[4], whose combination enables a superposition of stereomodels with DMR 5G, are used. This technology allows digitalization of break lines topologically related to the model. The initial data of the DMR 5G are supplied by stream lines, shore lines, terrain edges, terraces, embankments around roads and railways or escarpments and points with given elevation.

Within testing of the representation of the cartographic contour lines, an approach of contour line generalization using the Simplification (Point Remove and Bend Simplify) and Smoothing algorithms (PAEK, Bezier Interpolation) have been used. However, many serious topological errors, even by using a lesser degree of generalization, arisen. In this case the error elimination would be extremely time-consuming process, requiring extensive manual editing. The most common topological error was the intersection of adjacent contour lines. This problem occurred especially in rough terrain areas in the place of sudden changes of terrain (e.g. in areas of terrain edges, rocks and gully).

It was evaluated more software applications for model generalization in the Department of Cartography and Polygraphy of the Land Survey Office. Software Atlas DMT was finally chosen for elaboration of digital terrain model. This software allows processing of elevation data in ASCII format and elaboration of a digital terrain model in the form of TIN. This software is able to generalize digital terrain model within limited height and positional deviation. It protects topology including relations to break lines and stop lines. When testing, there was set up limit of the maximum height deviation of the digital terrain model in regards to the required accuracy and degree of generalization of the generated contour lines. The maximum height deviations occur in a generalized model only in very rough terrain (e.g. terrain

[3] Topol is a software for stereofhotogrammetry created by company TopoL Software s. r. o, Czech Republic.
[4] Atlas is a software for elevation models elaboration created by company Atlas, s.r.o., Czech Republic.

steps, gully). The digital terrain model generalization is performed in several cycles with regard to the required degree of generalization. However, the higher amount of cycles causes both a greater degree of digital terrain model generalization and also larger deviations of the contour lines from the terrain shape.

After generalization and smoothing of the digital terrain model in TIN form, cartographic contour lines are generated for the particular map scale. The contour line interval was chosen of 2 m for Basic Map of the Czech Republic in scale of 1: 10 000 (Fig. 5). In flat terrain the ordinary contour lines are replenished by auxiliary contour lines in interval of 1 m. There are other selected parameters, such as the degree of smoothness of contour lines within each triangle of TIN (number of triangle divisions) and the deviation limit influencing the output file size of contour lines. The lower limit value of the deviation is used, the size and precision of the output file is larger with less smoothed contour lines. At present, parameter settings for generalization DMR 5G and a contour line computation for the Basic Map of the Czech Republic of 1 : 10 000 has been optimized.

As the result of unification of the contour line interval for entire territory of the Czech Republic, the merging of adjacent contour lines occurs more often. This problem is solved by the suggested tool in the software ArcGIS. The function of this tool is identification of areas with greater slope, which cause merging of contour lines together, and designation of contour lines that should be made invisible during following graphical representation. The limit distance of the contour lines for their representation is based on printing and reproduction techniques. The parameters, such as width of the master contour lines (0,3 mm), ordinary and auxiliary contour lines (0,13 mm) and minimal distance between lines of contours due to their readability (0,2 mm), indicate a minimum distance of 1,82 mm between axis of adjacent master contour lines. If minimum distance between axes of adjacent master contour lines is not in accordance with the mentioned rule, the ordinary contour lines are cut at the edge of an affected area and the attribute “invisible” is assigned within this area.

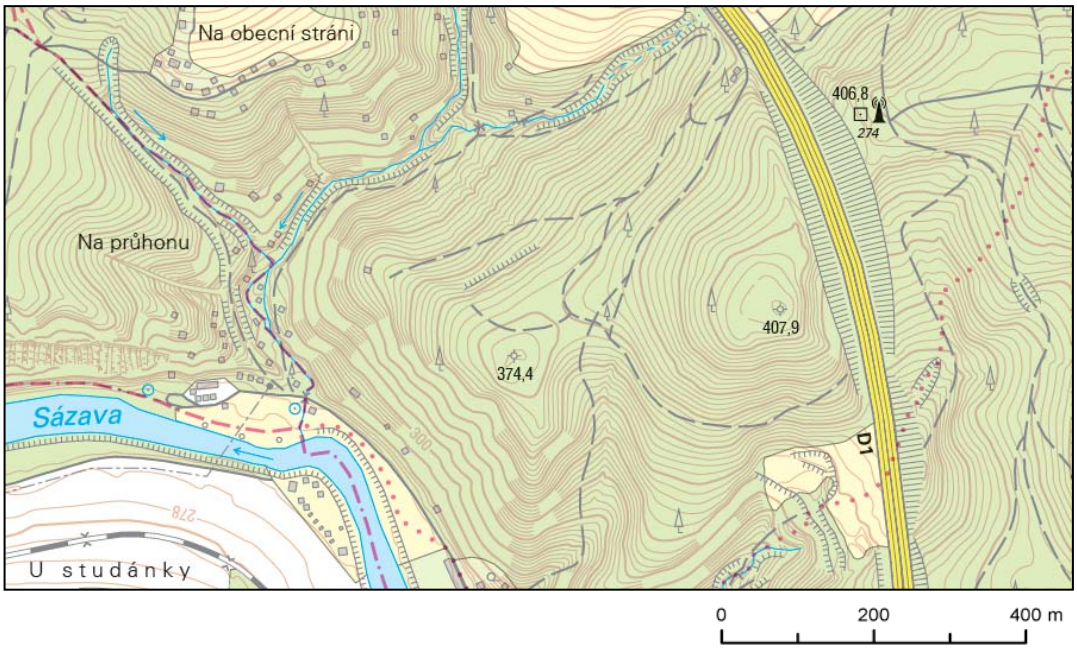

Figure 5: Representation of the new contour lines in maps in scale 1: 10 000

In 2011 the Department of Cartography and Polygraphy of Land Survey Office introduced a new cartographic system for production of the medium scale Basic Maps of the Czech Republic in scales of 1 : 10 000, 1 : 25 000, 1 : 50 000, 1 : 100 000 and 1 : 200 000. This system uses modern software ArcGIS, advanced methods and a new approach to map with the preservation of traditional values. The results should be the seamless maps of the Czech Republic in different scales, which require uniformed altimetry without conflict of contour lines on the frame edges of the map sheets. The problem is in the maps of 1 : 10 000. The old contour lines intervals were 5, 2 and 1 m depending on roughness of terrain and new interval, as mentioned above, is 2 m. Discontinuity of the contours has occurred in the seamless view map sheets with different contour line interval (see Fig. 6).

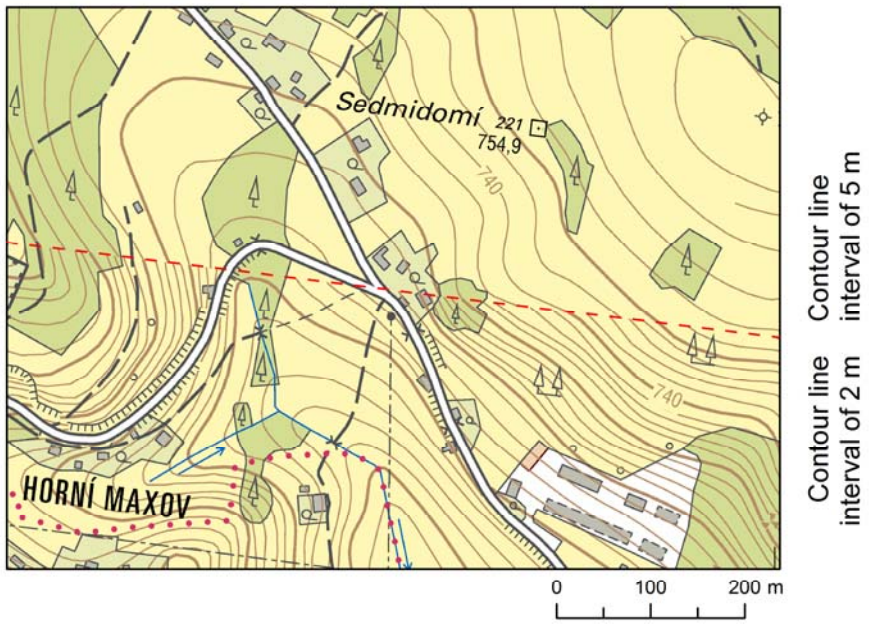

Figure 6: Seamless representation of map sheets in scale 1: 10 000

The aim of new representation of the cartographic contour lines in the Base Maps of the Czech Republic of 1 : 10 000 is, next to higher accuracy, unification of the contour interval. Auxiliary contour lines should be used only within flat areas. The contour intervals in other individual state maps of the Czech Republic remain the same and are uniformed within each scale.

5. Conclusion

The ALS data and derived elevation models are widely used within territorially orientated state and municipal information systems. The GIS applications are evidently going to use simplified methods for visualization of terrain using hypsometry, shaded relief but also simplified contour lines generated by application software in real time. It is possible to assume that software analysis will use mainly digital terrain models in grid or TIN form as a data elevation source. But new DMR 5G creates an appropriate potential for the creation of new cartographic contour lines of high quality to be used in the conventional Basic Maps of the Czech Republic.

The parameters of DMR 5G generalization and derivation of cartographic contour lines were tested on several terrain types of different shapes and ruggedness. The level of generalization is adapted to the appropriate cartographic representation in maps of 1 : 10 000 and 1 : 25 000. The cartographic model of contour lines and other cartographic symbols are interactively harmonized based on refined topographic data of ZABAGED® (terrain edges, water features, trigonometric points, etc.). As mentioned above, the generalization of elevation models is dependent on the appropriate generalization of terrain edges and stop lines that divide the model into sub-models where contour lines should be generated relatively independently.

The research is still in process. In the future we focus on the automatic generalization of terrain edges, model's stop lines and digital terrain models depending on the supposed scale of maps and charts.